A study on the magnetic properties of Al-doped sulphur spinel

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FeCr\textsubscript{2-x}Al\textsubscript{x}S\textsubscript{4} (0.1 \leq x \leq 0.5) samples were prepared by solid state reaction method. The crystallographic structure and magnetic properties of the fabricated compounds were investigated by x-ray diffraction, superconducting quantum interference device (SQUID), and Mössbauer spectroscopy. The crystal structure is determined to be a cubic spinel with the space group of Fd-3m and the lattice constants $a_0 = 9.998$, 9.994, and 10.010 Å, respectively. The temperature dependence of magnetization, measured from 5 to 300 K, suggests that FeCr\textsubscript{2-x}Al\textsubscript{x}S\textsubscript{4} (0.1 \leq x \leq 0.5) samples show ferrimagnetic behaviour. The magnetization followed a Curie-weiss law with a positive Curie temperature $\theta_{\text{cw}} = 160$ K, 141 K, and 129 K, respectively. FeCr\textsubscript{3}S\textsubscript{4} spinel was known to exhibit ferromagnetism below $T_N = 170$ K [1]. The decrease of Néel temperature compared with FeCr\textsubscript{3}S\textsubscript{4} could be interpreted by weakening of the exchange interaction by substitution of non magnetic Al ions. Mössbauer spectra of FeCr\textsubscript{2-x}Al\textsubscript{x}S\textsubscript{4} (0.1 \leq x \leq 0.5) were obtained at various temperatures ranging from 4.2 to 300 K. Magnetic hyperfine field and electric quadrupole interactions for $x = 0.5$ at 4.2 K have been fitted, yielding the following results: $H_{\text{hf}} = 120$ kOe, $\Delta E_Q = 2.27$ mm/s, $\theta = 37.0^\circ$, $\varphi = 10.0^\circ$, $\eta = 1.0$, and $R = 2.8$. The charge state of Fe ions for $x=0.5$ is ferrous (Fe\textsuperscript{2+}) as characterized by isomer shift $\delta = 0.72$ mm/s at 4.2 K.

Figure 1: The temperature dependence of FC magnetization curves for the FeCr\textsubscript{2-x}Al\textsubscript{x}S\textsubscript{4} (0.1 \leq x \leq 0.5) with the external field of 100 Oe.